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Influence of spacing and nutrient levels on yield, physiological parameters and nutrient uptake in short duration varieties of red gram [*Cajanus cajan* (L.) Millsp.]

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Abstract
The field experiment to assess the influence of spacing and nutrient levels on physiological parameters, yield and nutrient uptake in short duration red gram varieties was conducted in factorial RBD with three replications at College of Agriculture, Vellayani, Kerala during November 2018 – March 2019. The treatment combinations included two short duration varieties of red gram, [v_1: APK 1 and v_2: Vamban (Rg) 3], two spacings [s_1: 40 cm x 20 cm and s_2: 60 cm x 30 cm] and three nutrient levels [n_1: 40:80:40, n_2: 30:60:30 and n_3: 20:40:20 kg NPK ha^{-1}]. The results revealed that the variety APK 1 recorded the highest seed and haulm yield (0.99 and 3.57 t ha^{-1} respectively), and total uptake of P (11.67 kg ha^{-1}). Among the individual effects of spacing and nutrient levels, 40 cm x 20 cm and NPK @ 40:80:40 kg ha^{-1} were superior. In V x S x N interaction, the combination of APK 1, 40 cm x 20 cm and 40:80:40 kg NPK ha^{-1} recorded the highest total dry matter production, CGR, seed yield and P uptake. Based on the results, the short duration variety APK 1 at 40 cm x 20 cm at nutrient dose of 40:80:40 kg NPK ha^{-1} can be recommended for higher yield and nutrient uptake in red gram.

Keywords: Red gram, spacing, nutrient levels, physiological parameters, yield and nutrient uptake

Introduction

Red gram [*Cajanus cajan* (L.) Millsp.] Also called pigeon pea, is second in terms of area and production to chick pea in India, but the nation is the largest producer and consumer of red gram in the world. The average production is 3.29 million tonnes and productivity, 785 kg ha^{-1} [4]. The pulse is protein rich (22 %), which is almost three times that in cereals. In addition, red gram plays a crucial role in sustaining soil fertility by improving physical properties of soil and fixing atmospheric nitrogen. The traditional practice of cultivating long duration red gram varieties has in the recent years transformed to medium and short duration varieties adding to the cropping intensities.

Agronomic practices such as method of planting, spacing, fertilizer application, weed management, irrigation and method of harvesting are reported to influence the crop yields significantly [15]. Red gram is characterised by comparatively lower yields [11] and this has been attributed to cultivation in marginal and low fertility soils, poor management, diseases, high flower and pod drops, poor pod set and infestation by pod borers [1]. It is interpreted that an optimum row spacing and nutrient doses can ensure proper canopy development, flowering and pod setting in the crop. Keeping this in view, an experiment was undertaken to assess the influence of spacing and nutrient levels on physiological parameters, yield and nutrient uptake in short duration red gram.

Materials and methods

The experiment was conducted at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala located at 8°30' N latitude, 76°54' E longitude and at an altitude of 29 m above mean sea level. The initial soil status revealed it to be extremely acidic (pH 4.21), medium in organic carbon (0.81%) and available K (215.04 kg ha^{-1}), high in available P (47.14 kg ha^{-1}) and low in available N (100.35 kg ha^{-1}). The experiment was laid out in factorial RBD with three replications during November 2018. The treatment combinations included two short duration red gram varieties (v_1: APK 1 and v_2: Vamban (Rg 3), two spacings s_1: 40 cm x 20 cm, s_2: 60 cm x 30 cm and three nutrient levels (n_1: 40:80:40 kg NPK ha^{-1}, n_2: 30:60:30 kg NPK ha^{-1} and n_3: 20:40:20 kg NPK ha^{-1}). The soil acidity was corrected with lime application @ 850 kg ha^{-1} [6] during the land preparation. The basal dose of farm yard manure was incorporated @ 12.5 t ha^{-1} [18] and seeds were treated with *Rhizobium*, isolated from the root nodules of red gram plants grown in the farm @ 500 g per 10 kg and sown as per the spacings fixed. The NPK doses were supplied with the chemical fertilizers, urea (46% N), rajphos (18% P) and muriate of potash (60% K) as per treatments. The entire dose of P was given as basal, N and K, in two splits, basal and at 30 days after sowing (DAS).

Destructive sampling of three plants from each plot were done at 20 days interval for the observations on physiological parameters. Seed and haulm yields were recorded after the harvest and the uprooted plants were oven dried at 70° C until constant weight to assess the dry matter production. The nutrient uptake was calculated by multiplying the nutrient content with the total dry matter production at harvest. The data on the observations recorded were statistically analysed for ANOVA using the F-test[5] and wherever the treatment effects were significant, critical differences were computed.

Results and discussion

Physiological parameters

i. Total dry matter production: The variations in dry matter production (DMP) due to the varieties, spacing and nutrient levels are presented in Tables 1a, 1b and 1c. In the case of varieties, there were no significant differences in total DMP. The influences of spacing and nutrient levels were significant and the highest values were recorded with the closer spacing, 40 cm x 20 cm (s_1) and NPK dose of 40:80:40 kg NPK ha^{-1} (n_1), 3646.32 kg ha^{-1} and 3063.86 kg ha^{-1} respectively. The individual effects of treatments were manifested in the interactions also. Among the first order interactions, combinations involving the above treatments, v_1s_1, v_1n_1 and s_1n_1 resulted in significantly the highest dry matter accumulation. The interaction effects were significantly superior in the combination, $v_1s_1n_1$ (APK 1 + 40 cm x 20 cm + 40:80:40 kg NPK ha^{-1}), the total DMP being 4015.42 kg ha^{-1}.

The higher dry matter production in closer spacing is attributed to the increased plant population density compared to wider spacing [7].

The balanced application of NPK at the highest dose recorded the highest dry matter accumulation and is inferred to satisfy the crop requirements and promotion of growth and yields. The increased photosynthetic efficiency and production of photosynthates with the application of nutrients has been documented by several authors [2, 10, 14]. Accumulation of photosynthates results in higher dry matter production.

ii. Crop growth rate: Perusal of the data (Tables 1a, 1b and 1c) revealed that the CGR increased upto 40 – 60 DAS and thereafter declined. The spacing, 40 cm x 20 cm resulted the highest CGR at 20 days interval. With respect to the nutrient levels, 40:80:40 kg NPK ha^{-1} recorded the highest CGR during 20-40 DAS and 40-60 DAS, 2.36 g m^{-2} day^{-1} and 6.22 g m^{-2} day^{-1} respectively. Amongst the first order interactions, v_1s_1 and s_1n_1, recorded the highest CGR at 20 days interval. In V x N interaction, v_1n_1 recorded the highest CGR during 40-60 DAS. In V x S x N interaction, $v_1s_1n_1$ (APK 1 + 40 cm x 20 cm + 40:80:40 kg NPK ha^{-1}) recorded the highest CGR during all periods.

Crop growth rate is the assessment of crop biomass production per unit land area per unit time. In the present study the values were maximum for the period 40-60 DAS, indicating the most active growth stage during this period. Growth rates computed were significantly higher with the closer plant spacing of 40 cm × 20 cm at all the growth stages, which is mainly due to the higher biomass per unit area due to the higher plant density. Crop growth rate depends upon its radiation-use efficiency [3], which is the amount of intercepted photosynthetic active radiation and the efficiency of the crop to convert intercepted photosynthetic active radiation to aboveground biomass. The intercepted photosynthetic active radiation is related to canopy size, canopy architecture, and incident photosynthetic active radiation [8]. A lower plant density can result in decreased interception of the photosynthetically active radiation and hence photosynthetic efficiency. It is inferred that the better photosynthesis and carbohydrate accumulation is due to the larger leaf area during the grand growth phase 40-60 DAS. With maturity, senescence of the leaves and leaf drop were noticed resulting in the decline in CGR.

Yield

Varieties and management practices exerted significant influence on seed and haulm yield (Table 2a). The maximum yields were recorded in APK 1 (v_1), the spacing 40 cm x 20 cm (s_1) and the nutrient level 40:80:40 kg NPK ha^{-1} (n_1). The treatment combinations involving v_1, s_1 and n_1 registered highest yields in the first order and second order interactions (Tables 2b and 2c). The combination $v_1s_1n_1$ (APK 1+ 40 cm x 20 cm + 40:80:40 kg NPK ha^{-1}) registered the highest seed yield (1.36 t ha^{-1}) while haulm yield (4.68 t ha^{-1}) was highest in $v_2s_1n_1$ (Vamban (Rg) 3 + 40 cm x 20 cm + 40:80:40 kg NPK ha^{-1}).

Variations in red gram yields in APK 1 and Vamban (Rg) 3 are deduced to be the varietal differences and positive responses to nutrient application in terms of improved growth and yield in red gram have been illustrated [12, 19]. N, P and K have definite roles in plant growth [17] and with application of higher levels of fertilizers (40:80:40 kg NPK ha^{-1}) in soil in a definite ratio, will ensure readily available forms if the nutrients without antagonistic effects resulting in better growth and development of crops. The absorption of the essential nutrients in adequate quantities leads to higher photosynthetic activity and translocation of photosynthates to the sink, which results in higher seed yields [9]. The lower doses of 20:40:20 kg NPK ha^{-1} and 30:60:30 kg NPK ha^{-1} would not have been sufficient to realise its genetic potential. The higher plant population per unit area could explain the higher seed and haulm yields realized under closers pacing. The individual effects were mirrored in the interactions also.

Nutrient uptake

The total NPK uptake as influenced by the varieties and management practices are depicted in Tables 2a, 2b and 2c.

There was no marked variation in total N and K uptake due to the varieties. The highest total P uptake (11.67 kg ha^{-1}) was registered by the variety APK 1. The closer spacing and the higher nutrient level recorded the highest total NPK uptake. In first order interaction, v_1s_1 and v_2s_1 recorded the highest total NP and K uptake respectively and v_2n_1 and v_1n_1 resulted the highest NK and P uptake respectively. The interaction s_1n_1 recorded the highest total NPK uptake. In V x S x N interaction, $v_2s_1n_1$ (Vamban (Rg) 3 + 40 cm x 20 cm + 40:80:40 kg NPK ha^{-1}) recorded the highest total N and K uptake and $v_1s_1n_1$ (APK 1 + 40 cm x 20 cm + 40:80:40 kg NPK ha^{-1}) recorded the highest P uptake.

Nutrient uptake by crops is dependent on the biomass production and nutrient content in crops. The significantly higher values of uptake recorded under narrow spacing *i.e.* 40 cm x 20 cm (s_1) and with higher nutrient level 40:80:40 kg NPK ha^{-1}(n_1) would probably be due to the yields registered in these treatments [13, 16].

Table 1a: Effect of varieties, spacing and nutrient levels on total dry matter production and crop growth rate

Treatments	Total dry matter production (kg ha^{-1})	Crop Growth Rate (g $m^{-2}day^{-1}$)			
		20-40 DAS	40-60 DAS	60-80 DAS	80-100 DAS
Varieties (V)					
v_1 : APK 1	2830.02	2.31	5.41	4.31	1.90
v_2: Vamban (Rg)3	2773.03	2.28	5.14	4.30	1.91
SEm ±	21.83	0.012	0.115	0.145	0.10
CD (0.05)	-	-	-	-	-
Spacing (S)					
s_1: 40 cm x 20 cm	3646.32	2.99	6.91	5.50	2.54
s_2: 60 cm x 30 cm	1956.73	1.60	3.64	3.12	1.27
SEm ±	21.83	0.012	0.115	0.145	0.10
CD (0.05)	64.05	0.034	0.338	0.425	0.305
Nutrient levels (N)					
n_1: 40:80:40 kg NPK ha^{-1}	3063.86	2.36	6.22	4.51	1.99
n_2: 30:60:30 kg NPK ha^{-1}	2828.19	2.28	5.42	4.32	1.90
n_3: 20:40:20 kg NPK ha^{-1}	2512.52	2.25	4.19	4.10	1.82
SEm±	26.74	0.014	0.141	0.178	0.13
CD (0.05)	78.45	0.042	0.414	-	-

Table 1b: Interaction effect of varieties, spacing and nutrient levels on total dry matter production and crop growth rate

Treatments	Total dry matter production (kg ha^{-1})	Crop Growth Rate (g $m^{-2}day^{-1}$)			
		20-40 DAS	40-60 DAS	60-80 DAS	80-100 DAS
V x S interaction					
v_1s_1	3683.33	3.01	7.04	5.52	2.55
v_1s_2	1976.70	1.61	3.77	3.11	1.24
v_2s_1	3609.31	2.98	6.77	5.47	2.53
v_2s_2	1936.76	1.59	3.51	3.14	1.30
SEm±	30.88	0.016	0.163	0.205	0.15
CD (0.05)	90.56	0.048	0.478	0.601	0.432
V x N interaction					
v_1n_1	3124.74	2.38	6.44	4.57	1.99
v_1n_2	2858.57	2.28	5.61	4.31	1.86
v_1n_3	2506.74	2.26	4.17	4.06	1.83
v_2n_1	3002.98	2.34	6.01	4.45	1.98
v_2n_2	2797.81	2.28	5.22	4.34	1.94
v_2n_3	2518.31	2.24	4.20	4.14	1.81
SEm ±	37.82	0.020	0.200	0.251	0.18
CD (0.05)	110.91	-	0.586	-	-
S x N interaction					
s_1n_1	3952.08	3.09	8.01	5.77	2.57
s_1n_2	3695.21	2.96	7.13	5.55	2.54
s_1n_3	3291.67	2.93	5.59	5.18	2.50
s_2n_1	2175.64	1.63	4.43	3.26	1.40
s_2n_2	1961.18	1.60	3.71	3.10	1.27
s_2n_3	1733.38	1.57	2.79	3.02	1.14
SEm ±	37.82	0.020	0.200	0.251	0.18
CD (0.05)	110.91	0.059	0.586	0.737	0.529

Table 1c: Effect of V x S x N interaction on total dry matter production and crop growth rate

Treatments	Total dry matter production (kg ha^{-1})	Crop Growth Rate (g $m^{-2}day^{-1}$)			
		20-40 DAS	40-60 DAS	60-80 DAS	80-100 DAS
$v_1s_1n_1$	4015.42	3.12	8.15	5.91	2.58
$v_1s_1n_2$	3759.58	2.95	7.43	5.56	2.55
$v_1s_1n_3$	3275.00	2.95	5.55	5.11	2.52
$v_1s_2n_1$	2234.07	1.64	4.72	3.24	1.40
$v_1s_2n_2$	1957.56	1.61	3.80	3.06	1.18
$v_1s_2n_3$	1738.47	1.58	2.80	3.02	1.15
$v_2s_1n_1$	3888.75	3.05	7.87	5.63	2.57
$v_2s_1n_2$	3630.83	2.96	6.83	5.54	2.53
$v_2s_1n_3$	3308.33	2.92	5.62	5.26	2.48
$v_2s_2n_1$	2117.21	1.62	4.14	3.27	1.40
$v_2s_2n_2$	1964.79	1.59	3.61	3.14	1.35
$v_2s_2n_3$	1728.29	1.55	2.78	3.02	1.14
SEm ±	53.48	0.029	0.282	0.355	0.26
CD (0.05)	156.85	0.084	0.828	1.042	0.748

Table 2a: Effect of varieties, spacing and nutrient levels on yield and nutrient uptake

Treatments	Seed yield (t ha^{-1})	Haulm yield (t ha^{-1})	Nutrient uptake (kg ha^{-1})		
			Nitrogen	Phosphorus	Potassium
Varieties (V)					
v_1 : APK 1	0.99	3.57	71.99	11.67	35.13
v_2: Vamban (Rg)3	0.92	3.44	72.26	9.19	34.47
SEm ±	0.03	0.02	0.76	0.20	0.60
CD (0.05)	0.069	0.05	-	0.577	-
Spacing (S)					
s_1: 40 cm x 20 cm	1.19	4.48	95.41	13.59	43.92
s_2: 60 cm x 30 cm	0.72	2.53	48.84	7.26	25.68
SEm ±	0.03	0.02	0.76	0.20	0.60
CD (0.05)	0.069	0.05	2.216	0.577	1.741
Nutrient levels (N)					
n_1: 40:80:40 kg NPK ha^{-1}	1.06	3.75	76.33	12.07	37.62
n_2: 30:60:30 kg NPK ha^{-1}	0.94	3.46	73.14	10.43	34.54
n_3: 20:40:20 kg NPK ha^{-1}	0.88	3.31	66.92	8.79	32.24
SEm±	0.03	0.02	0.93	0.24	0.73
CD (0.05)	0.09	0.07	2.714	0.706	2.133

Table 2b: Interaction effect of varieties, spacing and nutrient levels on yield and nutrient uptake

Treatments	Seed yield (t ha^{-1})	Haulm yield (t ha^{-1})	Nutrient uptake (kg ha^{-1})		
			Nitrogen	Phosphorus	Potassium
V x S interaction					
v_1s_1	1.22	4.46	95.44	15.18	43.63
v_1s_2	0.78	2.68	48.54	8.15	26.63
v_2s_1	1.17	4.49	95.39	11.99	44.21
v_2s_2	0.66	2.38	49.14	6.38	24.73
SEm±	0.04	0.03	1.07	0.28	0.84
CD (0.05)	0.10	0.08	3.133	0.815	2.462
V x N interaction					
v_1n_1	1.07	3.75	75.73	13.26	37.18
v_1n_2	1.02	3.53	73.57	11.74	34.83
v_1n_3	0.90	3.44	66.67	10.00	33.39
v_2n_1	1.04	3.74	76.92	10.88	38.06
v_2n_2	0.86	3.39	72.70	9.11	34.26
v_2n_3	0.85	3.19	67.17	7.57	31.09
SEm ±	0.04	0.03	1.31	0.34	1.03
CD (0.05)	0.127	0.09	3.838	0.999	3.016
S x N interaction					
s_1n_1	1.34	4.64	101.96	15.58	48.20
s_1n_2	1.18	4.49	97.64	13.45	43.36
s_1n_3	1.07	4.30	86.63	11.75	40.20
s_2n_1	0.78	2.85	50.69	8.57	27.04
s_2n_2	0.69	2.43	48.63	7.40	25.73
s_2n_3	0.68	2.33	47.20	5.82	24.28
SEm ±	0.04	0.03	1.31	0.34	1.03
CD (0.05)	0.13	0.09	3.838	0.999	3.016

Table 2c: Effect of V x S x N interaction on yield and nutrient uptake

Treatments	Seed yield (t ha^{-1})	Haulm yield (t ha^{-1})	Nutrient uptake (kg ha^{-1})		
			Nitrogen	Phosphorus	Potassium
$v_1s_1n_1$	1.36	4.60	100.89	16.77	46.18
$v_1s_1n_2$	1.25	4.45	99.66	15.06	43.02
$v_1s_1n_3$	1.05	4.33	85.76	13.72	41.69
$v_1s_2n_1$	0.79	2.90	50.57	9.75	28.17
$v_1s_2n_2$	0.78	2.60	47.49	8.42	26.63
$v_1s_2n_3$	0.76	2.55	47.57	6.28	25.09
$v_2s_1n_1$	1.31	4.68	103.03	14.39	50.22
$v_2s_1n_2$	1.12	4.53	95.62	11.83	43.69
$v_2s_1n_3$	1.09	4.27	87.51	9.77	38.72
$v_2s_2n_1$	0.77	2.80	50.82	7.39	25.90
$v_2s_2n_2$	0.61	2.25	49.77	6.38	24.82
$v_2s_2n_3$	0.60	2.10	46.83	5.36	23.46
SEm ±	0.06	0.04	1.85	0.48	1.45
CD (0.05)	0.18	0.13	5.427	1.412	4.265

Conclusion
The study brings to light the superior performance of APK 1 over Vamban (Rg) 3, and among the spacing and nutrient levels tried, higher dry matter production, CGR, seed and haulm yield and NPK uptake were achieved with the closer spacing (40 cm x 20 cm) and the highest nutrient dose (40:80:40 kg NPK ha^{-1}). These were reflected in the interactions also and hence, for the cultivation of short duration red gram, the variety APK 1 at 40 cm x 20 cm spacing and an NPK dose of 40:80:40 kg NPK ha^{-1} can be suggested.

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